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Applicant Nikon Co., Ltd.

54) [Title of the invention]

Scanning electron microscope of the type with environment control.

57) [Summary]

[Aim]
Observation without charging of an insulating matter by an electron beam with a high acceleration voltage is made possible, and the signal to noise ratio is improved.

[Construction]
In a scanning electron microscope of the type with environment control, that has an electronic-optical system that carries out scanning by passage of an electron beam from an electron gun through an opening with a pressure limit and irradiation of a sample that is present in a gas with a low pressure, and that detects the secondary electrons from the above mentioned sample by a secondary electron detector, the above mentioned secondary electron detector is established in a position at a distance from the beam focussing point that is closer than the distance between the beam focus with respect to the above mentioned sample and the above mentioned opening with pressure limit. Moreover, it is a favourable situation that the objective lens of the above mentioned electronic-optical system is an in-lens type that has been equipped with two magnetic poles, and that observation is carried out, inserting the sample between these magnetic poles.

[What is claimed]

[Claim 1]
A scanning electron microscope of the type with environment control, with the characteristic that in a scanning electron microscope of the type with environment control, that has an elec-

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tronic-optical system that carries out scanning by passage of an electron beam from an electron gun through an opening with pressure limit and irradiation of a sample that is present in a gas with a low pressure, and that detects the secondary electrons from the above mentioned sample by a secondary electron detector,

the above mentioned secondary electron detector is established in a position at a distance from the beam focussing point that is closer than the distance between the beam focus with respect to the above mentioned sample and the above mentioned opening with pressure limit.

[Claim 2]

The scanning electron microscope of the type with environment control that has been described in claim 1, wherein the objective lens of the above mentioned electronic-optical system is equipped with two magnetic poles, and observation is carried out, inserting the sample between these magnetic poles.

[Claim 3]

The scanning electron microscope of the type with environment control that has been described in claims 1 or 2, wherein at least the edge of the above mentioned secondary electron detector that is directed to the radiation focus of the above mentioned beam, is chamfered.

[Claim 4]

The scanning electron microscope of the type with environment control that has been described in claim 3, wherein the above mentioned chamfering has a curvature that is larger than 0.5 mm.

[Detailed description of the invention]

[Field of use for the industry]

This invention pertains to a scanning electron microscope of the type with environment control, and it particularly pertains to a scanning electron microscope of the type with environment control wherein observation is possible without charging insulating matter, even if the acceleration voltage of the electron beam is high, and wherein a high voltage can be applied, even to

the secondary electron detector.

[Existing technology]

Hitherto, the so-called scanning microscope of the type with environment control (ESEM) is known as a scanning electron microsocpe (SEM) wherein a gas is introduced in the sample chamber. Such ESEMs have the advantage that for instance living matter can be observed without being killed. Moreover, a SEM wherein the magnetic lens that constitutes the objective lens, is split into two magnetic poles, the sample is inserted between these two magnetic poles, and observation is carried out in the situation that a magnetic field has been applied on the sample, is known as a SEM that has an in-lens type of objective lens.

Moreover, it is known that in ESEM, a secondary electron detector is established in the magnetic field of the objective lens, and in such an ESEM, the opening (aperture) with pressure control also serves as the secondary electron detector.

[Problems that should be solved by the invention]

Because now in the above mentioned ESEM, the opening with pressure control also serves as the secondary electron detector, (distance from the sample to the secondary electron detector) x (pressure of the gas), viz., the PD product, is small, and the sensitivity of the secondary electron detector is poor when the gas pressure in the sample chamber is low. When on the other hand, the gas pressure in the sample chamber is high, a problem was that scattering of the primary electron beam that irradiates the sample, is high, and that the non-scattered electron beam that has been finely focussed for irradiation of the sample, is small.

Moreover, because in the existing in-lens type of SEM, including ESEM, the surface was charged when it was decided to observe a sample of an insulating matter, there were unfavourable situations, such as the fact that the accelerating voltage of the electron beam is poor, 1 KV or less, and colour aberration is large, and that the electron beam is not squeezed to a very fine beam.

Moreover, because in an ESEM wherein a secondary electron detector has been established in the magnetic field, the position of the said secondary electron detector is far away from the

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point of incidence of the beam, a problem was that the surface of the sample is charged. Moreover, when in this case a high voltage is applied to the secondary electron detector, in order to prevent this charging, an unfavourable situation was that discharge occurred between the secondary electron detector and the sample.

As a result of a study of the problems in such an existing ESEM, the aim of this invention is to offer an ESEM wherein observation is possible without charging of insulating matter, even when the acceleration voltage of the electron beam is high, and wherein in addition, a high voltage is applied to the secondary electron detector, charging of the sample is eliminated, and the signal to noise ratio can be improved.

[Means to solve the problems]

In order to solve the above mentioned problems, this invention has the characteristic that in a scanning electron microscope of the type with environment control, that has an electronic-optical system that carries out scanning by passage of an electron beam from an electron gun through an opening with pressure limit and irradiation of a sample that is present in a gas with a low pressure, and that detects the secondary electrons from the above mentioned sample by a secondary electron detector, the above mentioned secondary electron detector is established in a position at a distance from the beam focussing point that is closer than the distance between the beam focus with respect to the above mentioned sample and the above mentioned opening with pressure limit.

Moreover, it is a favourable situation if the objective lens of the above mentioned electronic-optical system has a so-called in-lens construction, that has two magnetic poles, and wherein observation is carried out with insertion of the sample between these magnetic poles.

Moreover, the above mentioned secondary electron detector is arranged between the two magnetic poles of the objective lens of this in-lens type, and it is a fovourable situation if at least the edge that is opposite to the above mentioned beam focussing point of the said secondary electron detector, is made round.

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(Action)

Because in the above mentioned construction, the secondary electron detector is positioned most close to the point of incidence of the beam on the sample, almost all positive ions that have been produced in the space between the point of beam incidence and the secondary electron detector, incide in the point of beam incidence of the sample surface, without inciding in the opening with pressure limit, and neutralize the electrification of the surface that is charged with a negative potential. Consequently, no charge is produced, even if for instance an insulating matter is observed. Because the surface of the sample is charged with a slightly positive potential if an excess of the above mentioned positive ions incides in the surface of the sample, a repellence is produced when more positive ions are to incide, so that they do not incide. Therefore, the surface of the sample is on the other hand also not charged with a positive potential.

Moreover, in the case that an in-lens type is used as the objective lens, and the secondary electron detector is established between the two magnetic poles of this objective lens, a strong magnetic field, that does not perpendicularly cross the surface of the secondary electron detector, is present between the point of incidence of the beam and the secondary electron detector. Therefore, the secondary electrons are trapped around the magnetic flux of this magnetic field, and do not go straight ahead to the secondary electron detector. Consequently, the travelling distance of the secondary electrons from the surface of the sample to the secondary electron detector, is long, and even in a gas with a low pressure, sufficient collision with gas molecules occurs, and a large quantity of electron-ion pairs are formed. Therefore, the sensitivity of the secondary electron detector has a sufficiently high value. Moreover, the space that is formed by the above mentioned positive ions, is close to the position of incidence of the primary electron beam, and because these positive ions are not influenced by the magnetic field, they go straight ahead to the surface of the sample that has been negatively charged. Hereby, charging of the surface of the sample is efficiently prevented.

Moreover, by the establishment of a roundness in the edge section of the secondary electron detector, discharge between

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the secondary electron detector and the sample is made more difficult, and the voltage that can be applied to the secondary electron detector, can be raised, and the charge of the surface of the sample can be reduced further, and the signal to noise ratio can be improved.

[Example of execution]

Below, an example of execution of this invention is described. Figure 1 is a cross section of the construction of a scanning electron microscope of the type with environment control (ESEM) in the vicinity of the objective lens, that pertains to an example of execution of this invention. The device of this figure is equipped with an objective lens that has perforated magnetic pole 1 and non-perforated flat magentic pole 2 that is opposite to the said perforated magnetic pole 1. On perforated magnetic pole 1, magnetizing coil 3 has been wound. Moreover, deflectors 4a and 4b for scanning of the field of vision, that serve to scan the electron beam from the electron gun, that is not shown in the figure, and that has been established in the upper part of perforated magnetic pole 1, are established. The opening in the center of perforated magnetic pole 1 is opening with pressure limit 6, and by this opening with pressure limit 6, the pressure difference of the sample chamber between perforated magnetic pole 1 and non-perforated flat magnetic pole 2. is properly adjusted.

Moreover, between perforated magnetic pole 1 and non-perforated flat magnetic pole 2, opening with pressure limit 6, and coaxially, annular secondary electron detector 5 are established. Moreover, on non-perforated flat magnetic pole 2, electrostatic chuck 8 is established, and this electrostatic chuck 8 adsorbs sample 7 that is for instance a semiconductor wafer.

In the device of figure 1, the electron beam that is produced by an electron gun that is not shown in the figure, is deflected by deflectors 4a and 4b for field of vision scanning, and via opening with pressure limit 6, it incides in point of beam incidence 11 of sample 7 that has been adsorbed to electrostatic chuck 8 on non-perforated, flat magnetic pole 2. At this time, the electron beam is focussed by magnetic field 9 that is shown by the dotted lines between perforated magnetic pole and non-perforated flat magnetic pole 2, and it is deflected by deflec-

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tors 4a and 4b for field of vision scanning, with opening with pressure limit 6 as the deflection center.

When thus the electron beam incides in point of beam incidence 11 of sample 7 such as a semiconductor wafer, secondary electrons are emitted, corresponding to the state of the surface of the said point of beam incidence 11. In the form that they have been trapped by magnetic flux 9 of the objective lens, the emitted secondary electrons take a bent track as is for instance shown in 10, and loss potential energy during their travel by collision with the gas, and thereafter enter secondary electron detector 5.

Since thus, according to the above mentioned example of execution, secondary electron detector 5 is in a position that is closer to position of beam incidence 11 than opening with pressure limit 6, the positive ions that are generated in the vicinity of secondary electron detector 5 can effectively neutralize the charge of the surface of the sample that has been negatively charged.

Moreover, secondary electron detector 5 has been formed in an annular form, and because strong magnetic flux 9 passes in secondary electron detector 5 with this annular form by the objective lens without perpendicularly crossing the said secondary electron detector, secondary electrons that have been generated from the surface of sample 7 are trapped around this magnetic flux, and do not go straight ahead to the secondary electron detector. Therefore, the travelling distance of the secondary electrons is long, and sufficient collisions with the gas molecules occur, even in a gas with a low pressure, and secondary electron multiplication(?) is carried out, and detection with a high sensitivity is carried out.

Moreover, by the fact that a roundness is established in the edge section of secondary electron detector 5, discharge difficultly occurs, even if the voltage that is applied on secondary electron detector 5, is high, and the signal to noise ratio can be greatly improved. By the fact that, according to experiments, at least the edge of secondary electron detector 5 that faces the point of beam incidence has a curvature that is for instance 0.5 millidegrees or more, the voltage that can be applied on secondary electron detector 5 can be ca. 20% higher than in the past, with the result that the S/N ratio can be improved by ca.

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50%.

[Results of the invention]

According to this invention, as has been discussed above, observation is possible without charging an insulating matter, even if an electron beam with a high accelerating voltage is used, and because in addition a high voltage can be applied on the secondary electron detector, the signal to noise ratio can be greatly improved.

[Brief description of the figures]

[Figure 1]

is an explanatory drawing of a cross section that shows the construction of the vicinity of the objective lens of a scanning electron microscope of the type with environment control of an example of execution of this invention.

[Explanation of the symbols]

1 perforated magnetic pole
2 non-perforated flat magnetic pole
3 magnetization coil
4a, 4b deflector for field of vision scanning
5 secondary electron detector
6 opening with pressure limit
7 sample
8 electrostatic chuck
9 magnetic flux
10 track of secondary electrons
11 point of beam incidence

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